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ABSTRACT

Results of research to determine if an adaptive technique could be used to teach a physically complex psychomotor skill (specifically, performing on an arc welding simulator) more efficiently than the skill could be taught with a nonadaptive technique are presented. Sixty hull maintenance technician firemen and fireman apprentice trainees were selected randomly to perform on the simulator and were given pre- and post-training tests. Analysis of covariance was used on the data, and results indicate no significant difference between the effectiveness of adaptive and fixed schedules in training the skill studied. An introduction discusses the problem, purpose, and background of the study, as well as presenting a rationale for adoption and a history of adaptive applications. Research methodology is examined in terms of the subject, apparatus, experimental setting and design, and procedures. A discussion of the results, conclusions, and recommendations are presented. Six tables and eight figures supplement the text. It is recommended that since there may be a relationship between physical task complexity and the utility of adaptive/fixed training strategies, further research to understand the potential interaction between these two variables be undertaken. (LH)

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A COMPARISON OF ADAPTIVE AND NONADAPTIVE TRAINING
STRATEGIES IN THE ACQUISITION OF A PHYSICALLY
COMPLEX PSYCHOMOTOR SKILL

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The relative effectiveness of using adaptive and nonadaptive (fixed) strategies to facilitate acquisition of a physically complex psychomotor skill was investigated. In addition, task and practice difficulty levels were studied. Sixty subjects were each given pre- and posttraining tests and the data were evaluated by analysis of covariance. Results suggest no significant difference between fixed and adaptive techniques for the skill studied. The results are discussed and recommendations made.		

FOREWORD

The research was performed under Exploratory Development Task Area PF55.522.004 (Exploring New Technologies for Designing Navy Training Courses) and Work Unit Number PF55.522.004.01.58 (Innovative Uses of Feedback to Maximize the Transfer of Perceptual and Perceptual-Motor Training). The research was initiated in response to requests from the Chief of Navy Technical Training and the Service School Command, San Diego. Earlier efforts to this end can be found in: (1) NPRDC TR 74-33, Development and Validation of an Experimental Radiograph Reading Training Program by J. F. Brock, R. G. Wells, and M. L. Abrams, June 1974; and (2) NPRDC TR 75-13, Acquisition of a Psychomotor Skill Using Simulated Task Augmented Feedback by M. L. Abrams, H. B. Schow, and J. A. Riedel, October 1974.

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SUMMARY

Problem

In the military-industrial context, there are many tasks that require performing physically complex psychomotor skills. Since training personnel to perform such tasks is costly, it is essential that the most effective training strategies possible be determined to ensure that efficient training programs are utilized.

Purpose

The purpose of this research was to determine if an adaptive technique could be used to teach a physically complex psychomotor skill (specifically, performing on an arc welding simulator) more efficiently than the skill could be taught with a nonadaptive technique. Thus, adaptive and nonadaptive strategies were evaluated over a range of task and practice difficulty levels to assure the consideration of possible interaction effects between difficulty levels and training strategies.

Approach

Sixty Hull Maintenance Technician (HT) Firemen and Firemen Apprentice trainees enrolled at the HT "A" School, San Diego, California served as subjects for the study. The subjects were randomly selected and each subject assigned to one apparatus for the duration of the experiment.

A mixed 6x2x6x4 design was used with the following independent variables: (1) six levels of task practice difficulty, (2) adaptive or nonadaptive training, (3) six replications, and (4) four repeated measures of task difficulty. For each task difficulty level, the dependent variable was the posttest error rate. An analysis of covariance was utilized to evaluate the data.

The conceptual framework for the system designed for this study parallels the automated adaptive system outlined by Kelley and Kelley (1970) with the exception that the present system was not automated. Due to time and monetary considerations, the hardware in the present study was not developed to a level permitting automation. Therefore, the principle of adaption was tested manually, with the presumption that if adaptive techniques were effective, steps to automate the system could then be taken. In this light, some of the steps outlined by Kelley and Kelley (1970) were followed and others, such as the adaptive logic required for an automated system, were modified to fit present needs.

Conclusions and Recommendations

Based on the results of the study, the following conclusions and recommendations are made:

1. Adaptive and fixed schedules were equally effective in training the skill studied. There was no significant difference between the adaptive and fixed strategies, the different practice difficulty levels had no systematic effect on acquisition in either the adaptive or fixed groups and, overall, subjects demonstrated substantial learning of the task. Therefore, since a fixed schedule takes considerably less investment in development and implementation, it is recommended as the most cost-efficient method for training this particular skill (p. 25).
2. Simulator pretraining performance measures were highly correlated with final simulator performance ($r = .74$). Since final simulator performance has previously been found to correlate with welding performance ($r = .79$), this suggests a potential use of the apparatus as a predictive instrument for arc welding. Therefore, it is recommended that a study be conducted to evaluate using the apparatus as a selection vehicle for military-industrial arc welder training (p. 25).
3. Since there may be a relationship between physical task complexity and the utility of adaptive/fixed training strategies, further research is recommended to understand the potential interaction between these two variables (p. 25).

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INTRODUCTION

Problem

In the military-industrial setting, there are many tasks performed by substantial numbers of personnel, that require physically complex psychomotor skills.¹ Examples of these tasks include multidimensional tracking and aiming, switch pressing, fusing and defusing ordnance, precision soldering, silver brazing, and precision welding. Since training personnel to perform such tasks is costly, it is essential that the most effective training strategies possible be determined to ensure that efficient training programs are utilized.

Purpose

The purpose of this research was to determine if a physically complex psychomotor skill could be acquired more efficiently using an adaptive technique than by a nonadaptive technique. Specifically, the purpose was to compare adaptive and nonadaptive (fixed) strategies over a range of task and practice difficulty levels. Ranges of difficulty levels were specified in the design to assure that possible interaction effects between difficulty levels and training strategies would be considered.

Although adaptive training techniques have been used successfully to teach certain psychomotor skills (Hudson, 1962; Kelley, 1962, 1966, 1967; Gaines, 1967a, 1967b, 1968; & Caro, 1969), it has not been demonstrated that such techniques could also be used for teaching physically complex psychomotor skills. The specific skill studied in this investigation was performing a three-dimensional psychomotor task on a simulator designed to teach arc welding. For a brief description of the task, see page 7. The conceptual framework for the adaptive system developed for this study generally parallels the techniques outlined in Kelley and Kelley (1970). The described techniques include the design of an automated system, which is the most efficient way to use an adaptive technique. However, due to time and monetary considerations, the hardware in the present study was not developed to a level permitting automation. Therefore, the principle of adaption was tested manually with the presumption that, if adaptive

¹The term physically complex psychomotor skill is used in this study in an attempt to emphasize the physical complexity of the skill as differentiated from the "complex psychomotor" skills in previous adaptive studies, where the physical component was relatively much less complex.

techniques were effective, steps to automate the system could be taken at a later date. In this light, some of the steps outlined by Kelley and Kelley (1970) were followed and others, such as the adaptive logic required for an automated system, were modified to fit present needs.

Background

Rationale for Adaption

To cope with the increased training requirements imposed by the increasing complexity of performance tasks, many types of technological aids have been developed. These aids include computer-assisted instruction, film (including television), individualized modular programmed instruction, microfiche-based visual and/or sound displays, and simulators (Hilgard & Bower, 1966). Of these, simulators have been used most successfully for complex psychomotor skill training. However, even here, they have been used primarily to consolidate and maintain skills rather than to provide initial skill learning (Gagne, 1962). More recently, Abrams et al. (1974) demonstrated that a physically complex psychomotor skill could be acquired more efficiently with simulated-task augmented feedback, than with feedback normally provided by performing the task itself. Since evidence supports the hypothesis that simulators can provide initial skill acquisition as well as skill maintenance, learning strategies should be investigated to maximize their effect.

One learning strategy that has shown promise in terms of psychomotor skill acquisition and/or the use of simulation is that of simulator self-adjustment (adaption). For the purposes of the present investigation, adaption was defined as a training strategy for a task performed on a man-operated device or system where measurements are continually made of performance, and used to make appropriate changes in the task. To be adaptive, changes made must improve the system in some way. In this study, the task had to become more difficult as the trainee's performance improved, or less difficult when the trainee's performance deteriorated. This system is in contrast to a fixed strategy where the task or problem is unaffected by performance.

History of Adaptive Applications

Nonautomated adaption. The history of nonautomated adaptive training is probably as old as human instruction. Many, if not most, performance measurement and training systems are adaptive, with human beings performing the adaptive function. For example, instructors modify problems as a function of how well a student is performing. Group instruction may be a fixed system, or may be adjusted based on overall group performance. Some instructors are able to individualize instruction by giving

individual students problems based on their level of performance; however, in many schools, classroom instruction is geared to group performance.

As automation has developed, so have the applications of adaptive principles in a number of different but related areas (Kelley & Kelley, 1970). The two applications that are most relevant to the present effort are: (1) automated measurement, and (2) programmed and computer-aided instruction.

Automated measurement applications of adaption. Although automated adaptive techniques have a relatively recent history, von Békésy's audiometer developed in the late 1940s is one of the first apparatuses designed in a measurement context to utilize the adaptive principle (von Békésy, 1947). The audiometer determined the intensity threshold for pitch by automatically tracing the audio intensity-frequency curve. The device emits a tone and the subject changes a switch position when a tone goes from audible to inaudible, or vice versa. When the switch is moved, the intensity of the tone increases when it is inaudible and decreases when it is audible. Thus, the tone stays close to the subject's hearing threshold as it scans the auditory frequency range.

More recently, the use of the computer has facilitated the use of adaption in the measurement context. A review of adaptive computer controlled measurement in psychophysical applications is provided by Kappauf (1969). He points out that, as well as adjusting stimuli as a function of output, one can simultaneously utilize sequential analysis to determine when enough stimuli has been given. Therefore, testing can continue until the standard error of measurement has reached a preset level of confidence (Kelley & Kelley, 1970).

Psychomotor skill applications. In 1959, Henry Birmingham developed the first machine-controlled adaptive device in the continuous control field. The device was not a trainer; rather, it was a special-purpose unit to measure a human operator's ability to track high frequencies. When the subject's performance was poor (had a large error), the frequency of oscillation would slow down. When performance was good (had a small error), oscillation frequency automatically went up. Birmingham used the device to measure the "bandwidth" of the human operator; that is, the operator's frequency handling ability.

Using principles similar to Birmingham's, Birmingham, Chernikoff, and Ziegler (1962) developed a training device to teach continuous tracking skills. At this time, Hudson (1962) and Kelley (1962) were also developing training devices/simulators to teach tracking skills. However, there was an important difference in the adaption technique developed by Kelley. For example, in the adaptive tracking system developed by Hudson, as a trainee's performance improved, his average tracking error decreased. This decrease brought about an adaptive change in the system. However, in the adaptive tracking system developed by Kelley, average tracking error did not change as skill improved. Kelley (1969) states: "Whenever

the error deviates from the preset standard, the system changes until that amount of error is again present." Thus, if the trainee performed better than the standard, the system became more rigorous, and if he performed below the standard, the system got easier. Changes made in the system (adaptive variable), therefore, kept average tracking error constant. The major differences between a fixed, Kelley's adaptive, and Hudson's adaptive systems can be summarized as follows:

1. In a fixed system, the system remains constant and error rate changes.
2. In Kelley's system, the error rate remains constant and the system changes.
3. In Hudson's system, both the error rate and the system change with practice.

Kelley (1969) points out that it is scientifically more desirable to have one variable change systematically with adaption than two, and that this is a primary advantage of his system. By maintaining constant error, performance can be measured by changes in the adaptive variable alone rather than by changes in both the error rate and adaptive variable. This advantage can be demonstrated in different training situations. For example, in pilot training, the trainee must bring the aircraft to the lip of the runway, just as an experienced pilot would do, if he is to land safely. In precision welding, the trainee likewise must perform the same behaviors as the experienced welder if he is to fuse two pieces of metal successfully. Therefore, as Kelley (1969) states: "...it makes a great deal of sense to employ an adaptive system in which the allowable system error is established at the outset as a standard which the trainee must meet, while the system adjusts itself adaptively to whatever difficulty level the trainee is able to control with this standard error."

Other investigators have compared fixed with adaptive techniques in training. Gaines (1967a, 1968) found that the trainees in adaptive groups performed tracking tasks significantly better than those in fixed mode groups. In experiments on applying adaptive principles to flight simulator training, Lowes, Ellis, Norman, and Matheny (1968) found that adaptive training techniques were superior to the conventional (fixed) training technique. Also, in the area of pilot training, Ellis, Lowes, Matheny, and Norman (1971) found that adaptive techniques were superior where the task required maintaining a constant altitude during simulated air turbulence. Matheny (1969) and Wood (1969) have specifically used Kelley's technique. Matheny evaluated the Effective Time Constant (t_e), a measure of the speed with which one sees the results of control movement when operating most types of vehicle, as an adaptive variable. Results confirmed the notion that t_e appears to meet the criteria for an adaptive variable. Wood compared continuously adaptive changes to discrete changes of task difficulty in the training of a complex perceptual-motor skill. Results, however, suggested a fixed scheme with discrete changes superior to the adaptive mode. The author gives reasons for these results, and

comments on the subject's lack of motivation in the adaptive mode, since he is not able to steadily decrease his error (as displayed to him) during each trial. In summation, from the findings of studies comparing fixed and adaptive modes, there are sufficient data to warrant investigating the use of adaptive techniques for acquiring physically complex psychomotor skills.

METHOD

Subjects

The subjects (Ss) were Hull Maintenance Technician (HT) Firemen and Fireman Apprentice trainees enrolled at the HT "A" School, San Diego, California during July and August 1974. For the present study, 60 trainees awaiting training were randomly selected to participate in the experiment.

Apparatus

Configuration

As illustrated in Figure 1, the apparatus consisted of three major units:

1. A hand-held tracking stylus which automatically shortened in length when proper tip-to-target surface distance was maintained, or shut off if the parameters were exceeded. Incorporated in the stylus was an attitude sensor which indicated when angle deviations of the stylus went beyond a preset limit.
2. A target tracking box housing the mechanism which moved the target in a side-to-side motion along a predetermined path.
3. A control unit housing error sensors and digital recorders with the associated electronics for immediate operator feedback. The functions monitored by the error sensors were stylus tip-to-target surface distance, tracking, and the attitude of the stylus with respect to the target surface.

Task Description

To operate the apparatus, the subject had to move simultaneously in several different dimensions. As shown in Figure 2, he was required to perform the following actions:

1. He rotated his wrist axially, causing the tip of the stylus to move sideways within an approximate 1/4-inch limit (from a to b to a, etc., in the figure). Each sideways movement included a 1/32-inch forward movement at the rate of 48 oscillations and 3 inches per minute. At the same time, the trainee had to lift his arm vertically along the tracking path (from c to d), this motion required distinct pauses at the end of each limit.

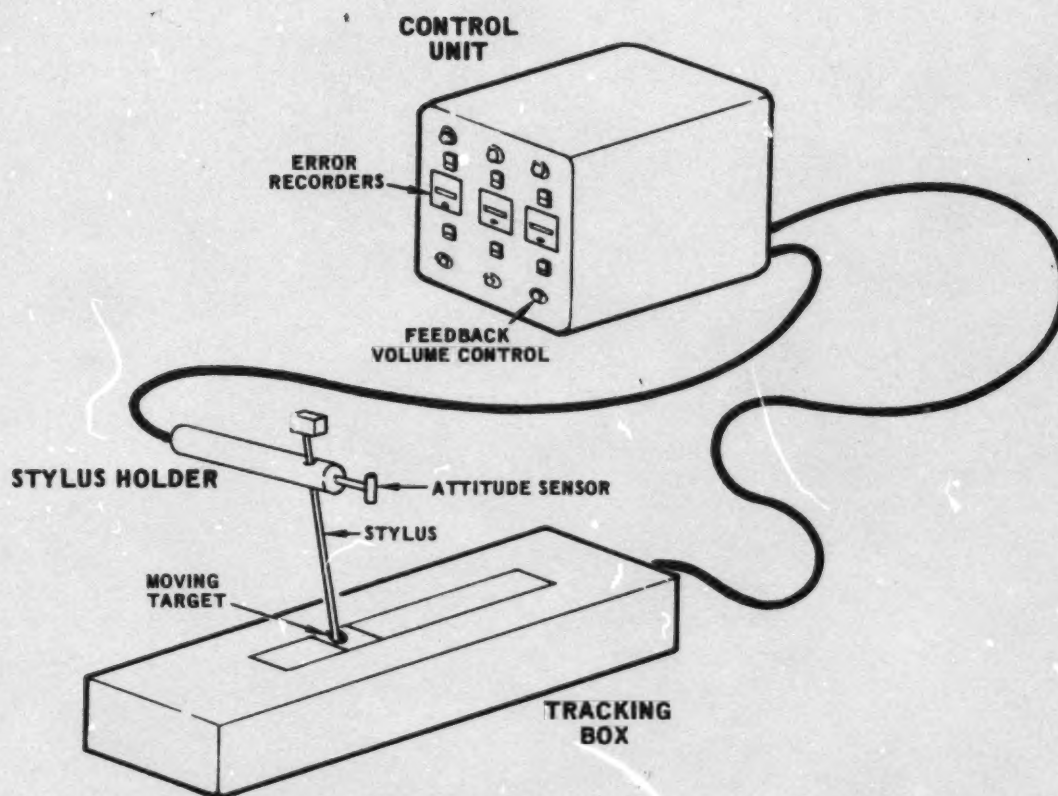


Figure 1. Configuration of the apparatus used in this study.

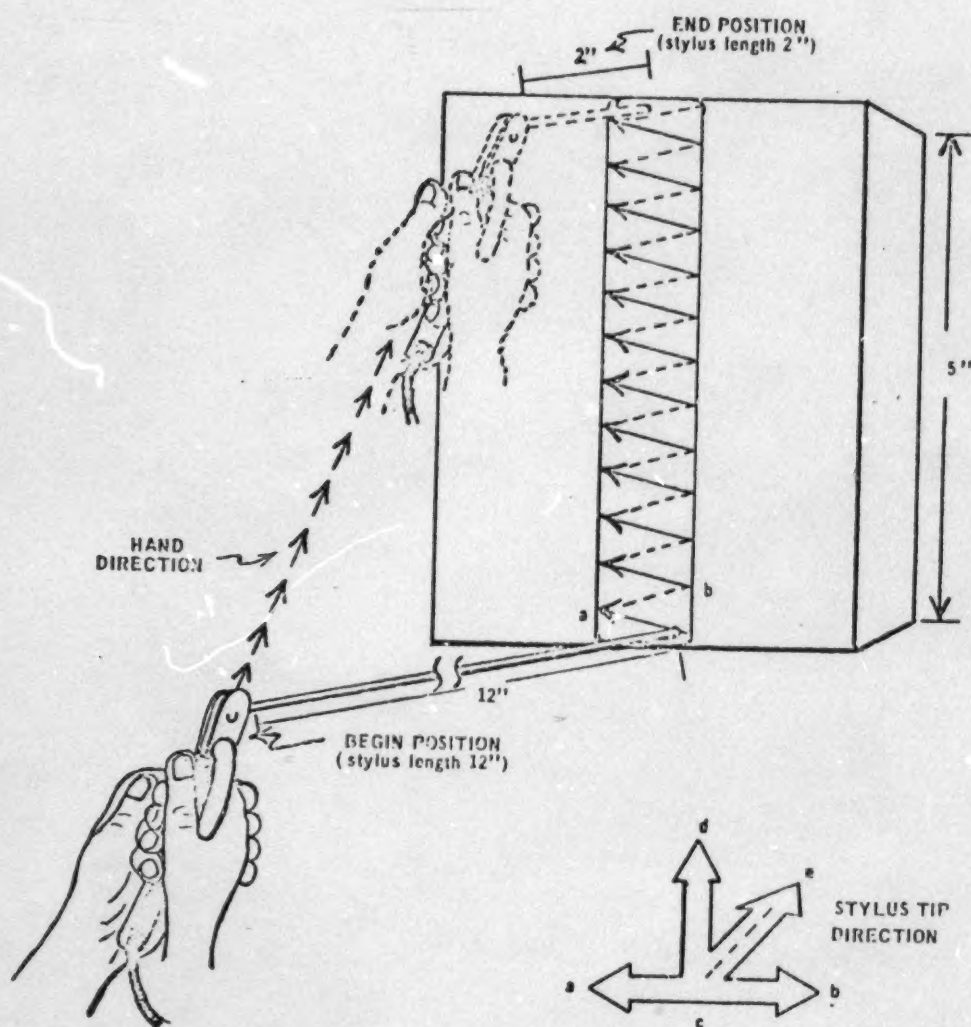


Figure 2. Movement while operating apparatus and consuming 10 inches of stylus (not to scale).

2. He pushed his arm forward to maintain correct stylus tip-to-target surface length as the stylus receded at a rate of 12 inches per minute (from c to e).

3. While moving as indicated above, he held his hand constant while continuously adjusting his arms to maintain a fixed stylus attitude of $5\frac{1}{4}$ - $15\frac{1}{4}$ with respect to the track unit surface.

Feedback Cues and Adaptive Variables

Traditionally, one of the major obstacles to acquiring a complex psychomotor skill has been the subject's inability to know which of the many task parameters he was exceeding and when. With the simulator, this obstacle was minimized by providing augmented feedback on the basic components of the task. In the present case, feedback was provided in the following manner:

1. Stylus tip-to-target surface distance. If the subject failed to maintain the proper tip-to-target distance ($1/8$ -inch + $1/16$ -inch), the stylus stopped receding, the white noise cue stopped, and the stylus light terminated.

2. Tracking. If the subject deviated from the side-to-side movement ($1/4$ -inch side-to-side and $1/32$ -inch forward at the rate of 48 oscillations and 3 inches per minute) while tracking, he received a 1000 Hz tone signal.

3. Stylus attitude. If the subject failed to keep the stylus holder at an attitude (i.e., the angle between the stylus and the target surface) $\pm 5\frac{1}{4}$ from a preset position, he received a 3000 Hz tone signal.

In addition to providing feedback, the sensitivity of the feedback sensors was adjustable for each of the skill dimensions. Thus, stylus tip-to-target surface distance, tracking, and stylus attitude could be utilized as adaptive variables because the performance measurements were sensitive to changes in the respective variables.

Experimental Setting

Each subject was assigned an apparatus for the duration of the experiment. Ten devices were used concurrently, and each device was housed in a 4'x4'x8' wooden booth. Each booth was equipped with an adjustable fixture for mounting the target tracking unit, so that the subjects could be positioned as physically comfortable as possible. The control unit and a timer, used to measure trail length, were positioned outside the booth for ease in recording data.

The feedback sensor circuits were adjusted to provide feedback and record errors when the designated parameters were exceeded. Feedback delays for tip-to-target surface distance, tracking, and attitude error sensors were set with respect to the experimental condition.

Experimental Design

A mixed 6x2x6x4 design was used with the following independent variables: (1) six levels of task practice difficulty, (2) adaptive or non-adaptive training, (3) six replications, and (4) four repeated measures of pre- and posttest difficulty level. The dependent variable was the posttest error rate measure.

The six levels of practice difficulty selected were based on the number of errors in each dimension it was expected that the S would make on his initial 7-minute trial (see Table 1). An approximation of S ability was achieved by analyzing each subject's pretrial efforts. Using this information, the parameters of his device were adjusted to place each S in the appropriate task difficulty level condition. The values of 30 to 300 were chosen in the stylus tip-to-target surface distance and tracking dimension, and 3 to 30 for the attitude dimension, because they represent an effective range for the apparatus. This information was derived from previous research, e.g., Abrams et al., 1974. The low limits were established to provide the opportunity for some improvement during the course of the experiment, and the upper limits, to assure that the feedback signals could be processed. In addition, the design contained two incomplete cells: (1) the low limits (30, 30, and 3) were dropped for the nonadaptive condition because it was felt significant learning could not occur after the first few trials; and (2) the high limits (300, 300, and 30) were dropped for the adaptive group because maintaining an error rate at that level throughout the experiment would have frustrated the subject unreasonably.

Procedure

Two experimenters (Es) ran the experiment with each E performing the same functions across replications. Ten Ss, with each S in a different experimental condition, were run simultaneously over six replications, and all groups received the same treatment. Upon arriving at the experimental area, Ss were randomly assigned to an apparatus and experimental condition (i.e., one of the five difficulty levels for either the adaptive or nonadaptive condition). Over the course of the experiment, all apparatuses were balanced over conditions to minimize individual machine effects.

TABLE 1

Preset Levels of Practice Task Difficulty
in the Three Task Dimensions

Condition	Tip-to-Target	Errors per 7-minute Trial	
		Tracking	Stylus Attitude
1	30	30	3
2	60	60	6
3	90	80	9
4	120	120	12
5	200	200	20
6	300	300	30

Immediately after assignment, Ss were given detailed briefing and task motivating instructions. This was followed by a 30-minute demonstration on how to operate the apparatus, including both its mechanical operation and strategies for using it to best advantage. Ss were then given the following familiarity practice: (1) 3 minutes of practice in each of the three task dimensions separately, and (2) four 7-minute trials with 3.5-minute intertrial breaks. Following questions, a 30-minute rest period was provided. This completed the orientation phase of the experiment.

Four 7-minute pretrials of varying difficulty levels (see Table 2) were then administered. The purposes for the range of pre- and posttest task difficulty levels were: (1) to eliminate confounding the practice difficulty independent variable with the dependent measure, i.e., a range of task difficulty levels in the pre- and posttrials ensured avoiding bias on the dependent measure in favor of a particular level of practice difficulty; and (2) to allow the evaluation of the experimental effects at various levels of task difficulty in performing the task.

Following the pretrials, the adaptive and nonadaptive Ss were started in their respective experimental conditions. No machine adjustments were made after that point for the nonadaptive group, however, machine adjustments were made for the adaptive Ss in accordance with this logic: every time the S showed either a 20% improvement or a 20% deterioration over three consecutive trials, the machine tolerances were either tightened or relaxed, respectively. Adjustments for tracking and attitude were made in 1/10-second intervals from a range of 0 to 1-second. Adjustments for stylus tip-to-target surface distance were made in 1/32-second increments from 1/32-inches to 8/32 inches.

TABLE 2

Difficulty Level Settings for Pre- and Posttrials*

Pre- Post- trial	Stylus Tip-to-Target Surface Distance	Track Delay	Stylus Attitude Delay
1	7/32 in.	.7 sec	.5 sec
2	5/32 in.	.5 sec	.4 sec
3	5/32 in.	.3 sec	.3 sec
4	2/32 in.	.15 sec	.2 sec

*The settings indicate the tolerance allowed prior to the onset of the error signal. Smaller tolerances indicate greater task difficulty.

All Ss were given 100 7-minute trials with 3.5 minute intertrial rest periods. However, because the stylus shut off when stylus tip-to-target surface distance parameters were exceeded, the 7-minute trials usually averaged 9.5 minutes real time. Five 50-minute sessions, each made up of four trials and separated only by 10-minute breaks, were run consecutively for 5 consecutive days. Error data on track, attitude, and stylus tip-to-target surface distance were recorded for all trials, including the pre- and posttrials.

Upon completion of the training sessions, the Ss were administered the posttrials exactly as the pretrials had been given. After the post-trial data were recorded, the Ss checked out of the experimental program and continued with their regular HT "A" School training.

RESULTS

The posttrial data were evaluated using an analysis of covariance, with pretrials used as the covariate. Data for the "attitude of stylus" dimension of the task were discarded due to apparatus unreliability on that dimension. The results of the analysis for the three modes (stylus tip-to-target distance, tracking, and these two variables combined) are summarized in Tables 3, 4, and 5, respectively. The correlation between variate and covariate for stylus tip-to-target surface distance was .71; for tracking, .69; and for the two variables combined, .74. For all three modes, there were no significant differences among the various levels of practice difficulty. Similarly, the effects of the training schedules (adaptive and nonadaptive) were not found to be significantly different. While neither of the main effects were significant, the average percent of improvement between pre- and posttests for all Ss was 65.58% out of a possible 100%. This was computed by the percent gain of possible gain method No. 1 (McGraw, 1955). As can be seen from the tables, a significant interaction was found between the levels of practice difficulty and training schedules for all three modes. Figures 3, 4, and 5 show the graphs of the covariate adjusted mean error rate for each interaction.

A test of significance for linearity was performed, and results suggest no significant linear trend for the adaptive and nonadaptive conditions across levels of practice difficulty.

An analysis of covariance was also used to determine whether the four levels of error rate used for both the pre- and posttests were significantly different. Table 6 demonstrates the results of this analysis for the three dimensions. As can be seen from this table, there was a significant difference between the four levels of pre- and posttest error rate for each of the three dimensions.

TABLE 3

Analysis of Covariance Results for Stylus
Tip-to-Target Surface Dimension

Source	df	MS	F
A - Level of Practice Difficulty	5	1686.39	0.95
S/A	234	1772.48	
TOTAL	239		
B - Training Schedule	1	1920.43	1.08
S/B	238	1770.05	
TOTAL	239		
AxB	3	8020.95	4.75*
S/AB	230	1686.77	
TOTAL	233		

*p < .01

TABLE 4

Analysis of Covariance Results for Tracking Dimension

Source	df	MS	F
A - Level of Practice Difficulty	5	2742.82	1.02
S/A	234	2702.06	
TOTAL	239		
B - Training Schedule	1	52.38	.02
S/B	238	2714.05	
TOTAL	239		
AxB	3	9761.08	3.74*
S/AB	230	2610.36	
TOTAL	233		

*p < .01

TABLE 5

Analysis of Covariance Results for Stylus Tip-to-Target
Surface and Tracking Dimensions

Source	df	MS	F
A - Level of Practice Difficulty	5	6123.39	.95
S/A	234	6537.70	
TOTAL	239		
B - Training Schedule	1	2005.00	.31
S/B	238	6449.72	
TOTAL	239		
AxB	3	34421.33	5.68*
S/AB	230	6057.67	
TOTAL	233		

*p < .01

TABLE 6

Analysis of Covariance Results for Trials in the
Three Task Dimensions

Source	df	MS	F
I. Stylus Tip-to-Target Surface Dimension			
A - Trials	2	122995.56	47.28*
S/A	237	2601.34	
TOTAL	239		
II. Tracking Dimension			
A - Trials	2	212161.81	61.22*
S/A	237	3465.11	
TOTAL	239		
III. Stylus Tip-to-Target Surface and Tracking Dimensions			
A - Trials	2	644615.50	74.01*
S/A	237	8709.64	
TOTAL	239		

*p < .01

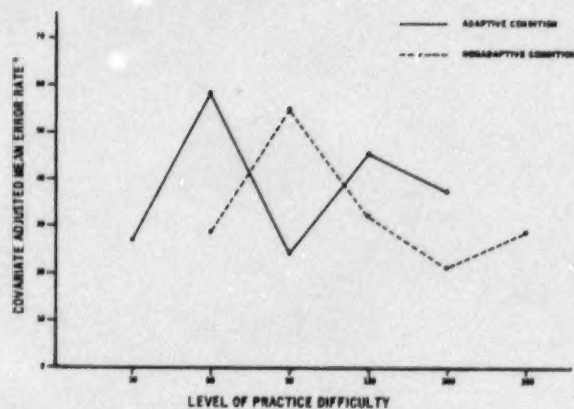


Figure 3. Adjusted mean error rate across level of practice difficulty for adaptive and nonadaptive conditions for the tip-to-target surface dimension.

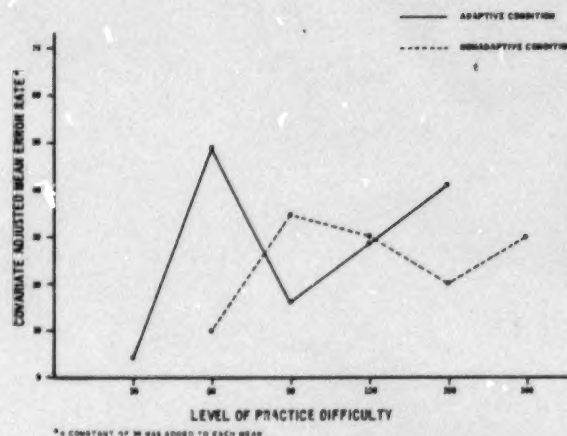


Figure 4. Adjusted mean error rate across level of practice difficulty for adaptive and nonadaptive conditions for the tracking dimension.

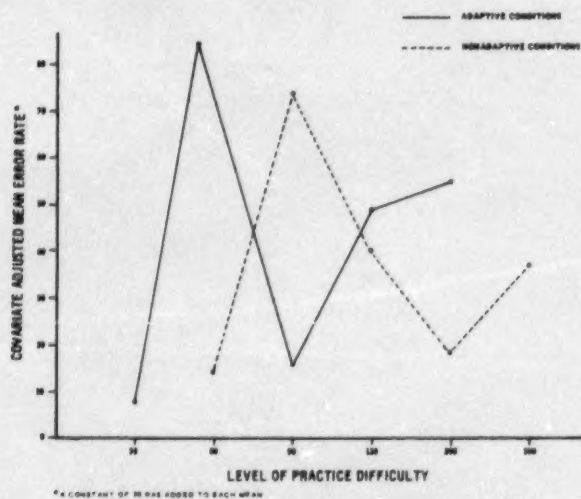


Figure 5. Adjusted mean error rate across level of practice difficulty for adaptive and nonadaptive conditions for both the tip-to-target surface and tracking dimensions.

DISCUSSION

The basic purpose of this research was to compare adaptive and non-adaptive strategies over a range of task and practice difficulty levels for a complex psychomotor skill. The range of practice difficulty levels was specified in the design to assure that possible interaction effects between practice difficulty levels and training strategies would be considered. The results indicate that there were no significant main effects and no linear interaction.

It had been anticipated that the adaptive mode would be most effective at low practice difficulty levels and the fixed mode, at high practice difficulty levels. This anticipation was based on the following premises: (1) in the fixed mode, a low difficulty level would not allow for skill acquisition at increased task difficulty levels, thereby limiting the standards at which learning could take place; and (2) in the adaptive mode, a high error signal rate would frustrate and discourage the trainee because he could not escape from it or note any improvement in terms of decreasing error signals. This latter premise is consistent with the concept of negative reinforcement (i.e., acquisition will occur due to the cessation of aversive stimuli). Figure 6 illustrates the predicted interaction.

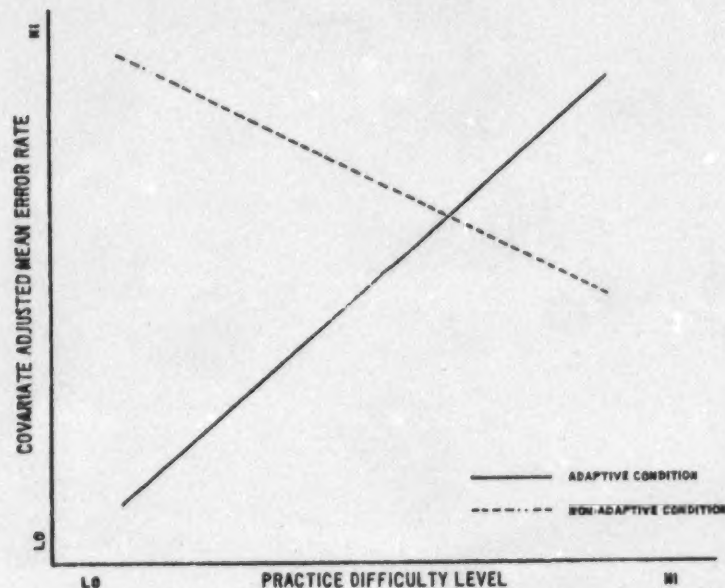


Figure 6. Predicted interaction between task difficulty and training strategy.

There are several ways to explain the absence of a significant main effect and the apparent randomness of the interaction curves plotted in Figures 3, 4, and 5. First, the performance measurement may not have been sufficiently sensitive to variations in the adaptive variable. If this were the case, the system would not be able to maintain a constant performance measure through changes in the adaptive variable. Second, the dependent measure may not have accurately measured the behavior in question. For example, it is possible that good and poor performances were not reflected adequately in the performance measure. Finally, there may not have been a difference between nonadaptive and adaptive techniques when teaching the skill.

The data collected shows that there is no support from the first explanation. Figures 7 and 8 demonstrate the relationship between changes in the adaptive variables and the performance measurement. Figure 7 shows that there were definite changes in performance as the adaptive variable was adjusted in the tracking dimension, and Figure 8 clearly illustrates similar changes in performance in the stylus tip-to-target dimension, except during trials 2 and 3. The reason for the lack of changes here is because the dimension did not change for these trials. It can also be seen that the posttrial measures had a more gradual slope than pretrial measures. This probably occurred because the learning that took place during training decreased sensitivity to changes in difficulty. Thus, it appears that the dependent variable was sensitive to the changes in the adaptive variables. This reinforces the differentiation between the experimental groups because the difficulty level conditions were controlled by alterations in the adaptive variables. There is no doubt that the different groups actually experienced different conditions. Thus, this invalidates any attempt to explain the lack of differences between groups in terms of a lack of experimental difference between the conditions.

Also, there is no support for the second explanation. In previous research (Abrams et al., 1974), a significant correlation ($r = .79$) was found between posttrials (the dependent variable) and an independent criterion, precision welding. This showed that good and poor performance was apparently being validly discriminated by the dependent measure.

The most probable alternative for explaining the finding is that there were no real differences in learning derived by employing either strategy. Since both groups improved 65% out of a possible 100%, learning seems to be taking place. Previous research (Abrams et al., 1974) found that an improvement of 50% out of a possible 100% for such a short-time period on this task was sufficient to infer that adequate skill acquisition was taking place. However, for adaptive training to be feasible, it must be demonstrated that it is clearly superior to other training methods since additional initial expenses are required to develop and integrate it into a system. Two primary hypotheses can be derived from the present results which explain why the adaptive conditions were not superior: (1) the Ss in the adaptive mode were not able to detect progress because

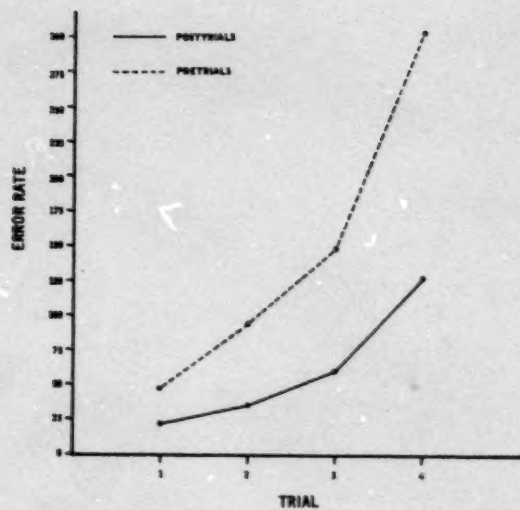


Figure 7. Pre- and posttest error rates across trials in the tracking dimension.

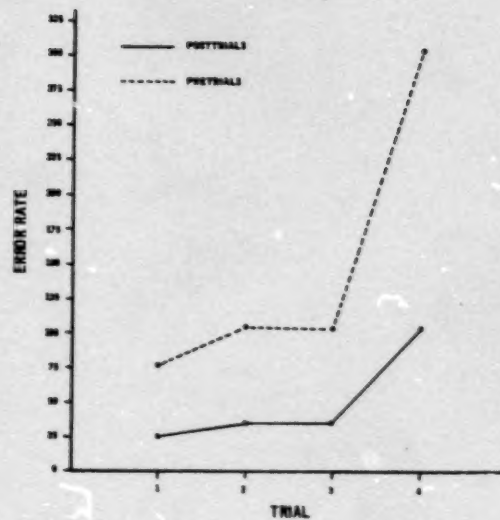


Figure 8. Pre- and posttest error rates across trials in the stylus tip-to-target dimension.

their error signal rates were held constant, and thus were subjected to negative motivational effects, and (2) adaptive techniques are not applicable in the present case due to the complexity of the task.

Support for the former hypothesis can be found in Wood (1969). He suggested that previous comparisons between adaptive and fixed-difficulty tracking tasks have tended to have a built-in bias in favor of the adaptive conditions. A better comparison would employ a fixed-difficulty tracking task whose level of difficulty increased by discrete jumps of a magnitude such that at any time in the training period the fixed-difficulty level would be equal to the average difficulty level of the adaptive task. Wood performed such a comparison and found the fixed scheme to be superior as a training technique to the adaptive mode. In explaining the results, Wood suggested that Ss lacked motivation in the adaptive mode because the task did not allow Ss to plot continuing reduced error rates.

In the present study, an attempt was made to minimize this effect by verbally informing the adaptive condition Ss of their progress in terms of the changes made in the adaptive variables. There is little doubt that error signal decreases are important if operator feedback is not available on the adaptive variables. However, when new operator feedback cues (changes in adaptive variables) were introduced, it was difficult to tell whether such information was sufficient to maintain the motivation of those Ss normally motivated by decreases in error signal rate.

The second hypothesis concerning task complexity seems more plausible in explaining the present results. Much of the research that has been conducted in the area of psychomotor skill acquisition has suffered from limited generalizability. For example, many investigators have evaluated various learning principles (i.e., massed versus distributed practice, practicing a response, reinforcement, etc.), and training strategies (adaptive and nonadaptive) on relatively simple physical tasks (e.g., rotary pursuit), or on tasks that stress the cognitive skills (i.e., information processing) relatively more than physical complexity (e.g., piloting skills) (Kelley and Wargo, 1968). Many of these studies have been of short duration in terms of time spent practicing the task. Actual practice times generally have averaged 20 minutes (e.g., Bell, 1942; Kientzle, 1946, 1949; & Kimble, 1949), and ranged from 80 minutes (Bilodeau, 1952) to 3 minutes (Duncan, 1951). It would seem reasonable to suggest that, in a training context, a complex skill would require more than such short terms of practice. Evidence derived from such studies cannot be generalized to other studies investigating the acquisition of a physically complex psychomotor skill because such skills may, in fact, represent a different class or classes of behavior.

Abrams et al. (1974) found that physically complex psychomotor skills are in fact different than simple psychomotor skills and, therefore, technical training strategies or techniques should consider the task complexity. The work of Fleishman (1962) supports this finding. Fleishman's notions of task taxonomy were based on a factor analysis of abilities involved in different skills, at different stages of practice. His

conclusions suggested that: (1) the pattern of abilities contributing to the performance changes with practice, and (2) each task gives rise, at its later stages, to a factor specific to those stages of practice. In one factor analysis of a complex tracking task, he demonstrated the importance of spatial orientation early in training, and multilimb coordination late in training. However, a disadvantage of this approach was that no generalization from one task to another was possible because the factor analysis had been done on one specific task, and it would be awkward to do a factor analysis for every task taught (Hilgard & Bower, 1966). The important point here, pointed out by both Fitts (1962) and Fleishman (1962), is that even tasks that appear to be simple are often quite complex because the psychological processes involved can range from simple associative learning to higher forms of information processing. In the present study, the task may have involved processes that do not occur in many less physically complex tasks. For example, in a rotary pursuit task, the operator must try to keep a stylus in contact with the target. However, in the present task, he had to simultaneously move in three different dimensions (see Figure 2 and task description.)

The hypothesis that physically complex psychomotor skills may require different training strategies than less complex skills also can derive support from the literature on verbal learning. For example, in teaching reading, an instructor will use different strategies to teach word recognition and comprehension. In associative learning tasks, the learner may use paired-associate strategy for simpler tasks and concept identification for more complex tasks. Although the latter example is a learner strategy rather than a teaching strategy, the point remains that by varying the dimension of task complexity, the learner himself may select a different strategy for task skill acquisition. If this is true, it would seem reasonable to predict that for various levels of complexity, different teaching strategies may also provide a different impact on learning.

There is also the possibility that the strategies the student employs in a physically complex task may vary during different learning phases. Evidence was found suggesting that the attitude dimension in the present task was acquired most rapidly (Abrams et al., 1974). It is plausible that the student concentrates on one dimension or set of dimensions for a time and, when progress is perceived, shifts his attention to another dimension or set of dimensions. In addition, the student may (1) utilize different strategies on the same dimension of the task over time, (2) alternate attention between dimensions using the same strategy, or (3) vary strategies and attention over a course of training to accommodate his own abilities and past learning. The result is a very complex set of behaviors to facilitate learning the task. The work of Fleishman (1962) conducted on task taxonomy supports these notions. While adaptive techniques have been found to be very successful in the training of some skills, it may be that as a physical task becomes more complex the adaptive variables begin interacting with each other so that any overall gain is lost. For example, in the present study, if a subject were assigned to the 90 errors level in the adaptive group, then both the stylus tip-to-target surface and tracking dimensions would be kept at 90 errors throughout training.

If the subject improved in the stylus tip-to-target surface dimension so that error level dropped, the controls on the stylus tip-to-target surface dimensions would be adjusted to bring the error level back up. However, if the tracking errors remained stable, that dimension would never be changed. One dimension could thus be adjusted while a second dimension could remain unchanged, or not adjusted nearly as much. The effect of such interactions between adaptive variables for physically complex psychomotor tasks has never been studied. A possibility for future research would be to address this problem by defining a physically complex psychomotor skill with greater precision and separating out each adaptive variable first for separate and then combined study.

Thus, in various areas of learning, evidence suggests that the complexity of the task is potentially important for understanding the strategy the learner utilizes and the training strategy the teacher must develop. In the area of psychomotor skill training, tasks of clearly differing complexities often have not been sufficiently discriminated. This is unfortunate since training strategies should be developed only after thoroughly analyzing the task. In the present case, a training technique that was successfully employed with other psychomotor skills did not generalize to a more physically complex task, thus indicating a limitation of that strategy. Therefore, efforts should be focused on developing strategies within different theoretical frameworks and tests of these approaches should be made to determine the most efficient methodology.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the study, the following conclusions and recommendations are made:

1. Adaptive and fixed schedules were equally effective in training the skill studied. There was no significant difference between the adaptive and fixed strategies, the different practice difficulty levels had no systematic effect on acquisition in either the adaptive or fixed groups, and overall subjects demonstrated substantial learning of the task. Therefore, since a fixed schedule takes considerably less investment in development and implementation, it is recommended as the most cost-efficient method for training this particular skill.

2. Simulator pretraining performance measures were highly correlated with simulator final performance ($r = .74$). Since final simulator performance has previously been found to correlate with welding performance ($r = .79$), this suggests a potential use of the apparatus as a predictive instrument for arc welding. Therefore, it is recommended that a study be conducted to evaluate using the apparatus as a selection vehicle for military-industrial arc welder training.

3. Since there may be a relationship between physical task complexity and the utility of adaptive/fixed training strategies, further research is recommended to understand the potential interaction between these two variables.

REFERENCES

- Abrams, M. L., Schow, H. B., & Riedel, J. A. Acquisition of a psychomotor skill using simulated-task augmented feedback (Evaluation of a welding training simulator). San Diego: Navy Personnel Research and Development Center, October 1974. (Technical Report TR 75-13)
- Bell, H. M. Rest pauses in motor learning as related to Snoddy's hypothesis of mental growth. Psychological Monographs, 1942, 54, No. 1 (Whole No. 243).
- Bilodeau, E. A. Massing and spacing phenomena as functions of prolonged and extended practice. Journal of Experimental Psychology, 1952, 44, 108-113.
- Birmingham, P. P. The instantaneous measurement of human operator bandwidth. (Paper presented at the 8th Annual Conference on Manual Control), Stamford, Connecticut: Dunlap and Associates, Inc., 1959.
- Birmingham, H. P., Chernikoff, R., & Ziegler, P. N. The design and use of "equalization" teaching machines. (Paper presented at IRE International Congress on Human Factors in Electronics), Long Beach, California, 1962.
- Brock, J. F., Wells, R. G., & Abrams, M. L. Development and validation of an experimental radiograph reading training program. San Diego: Navy Personnel Research and Development Center, June 1974. (Technical Report TR 74-33)
- Caro, P. W., Jr. Adaptive training--an application to flight simulation. Human Factors, 1969, 11(6), 569-575.
- Duncan, C. P. The effect of unequal amounts of practice on motor learning before and after rest. Journal of Experimental Psychology, 1951, 42, 257-264.
- Ellis, N. C., Lowes, Ann L., Matheny, W. G., & Norman, D. A. The feasibility of using an adaptive technique in flight simulator training. Ergonomics, May 1971, Vol. 14(3), 381-390.
- Fitts, P. M. Factors in complex skill training. In R. Glaser (Ed.) Training Research and Education. Pittsburgh: University of Pittsburgh Press, 1962, 177-197.
- Fleishman, E. A. The description and prediction of perceptual-motor skill learning. In R. Glaser (Ed.) Training Research and Education. Pittsburgh: University of Pittsburgh Press, 1962, 137-175.

- Gagne, R. M. Simulators. In R. Glaser (Ed.), Training Research and Education. Pittsburgh: University of Pittsburgh Press, 1962.
- Gaines, B. R. Automated feedback trainers for perceptual-motor skills. Final report to Ministry of Defense. England: University of Cambridge, Department of Experimental Psychology, September 1967(a).
- Gaines, B. R. Teaching machines for perceptual-motor skills. England: University of Cambridge, Department of Experimental Psychology, 1967(b).
- Gaines, B. R. Adaptively controlled instruction for a tracking skill. Trans. NATO Conference on Programmed Learning Research, Nice, 1968.
- Hilgard, E. R., & Bower, G. H. Theories of Learning. New York: Appleton-Century Croft, 1966.
- Hudson, E. M. An adaptive tracking simulator. (Paper presented at IRE First International Congress on Human Factors in Electronics.) Long Beach, California, May 1962.
- Kappauf, W. E. Use of an on-line computer for psychophysical testing with the up-and-down method. American Psychologist, 1969, 24(3), 207-210.
- Kelley, C. R. Self-adjusting vehicle simulators. In The Predictor Instrument: Final Report and Summary of Project Activities During 1961. Technical Report to the Office of Naval Research. Stamford, Connecticut: Dunlap and Associates, Inc., January 1962.
- Kelley, C. R. Adaptive simulation. Santa Monica, California: Dunlap & Associates, Inc., Technical Report to the Office of Naval Research, August 1966.
- Kelley, C. R. Further research with adaptive tasks. Santa Monica, California: Dunlap & Associates, Inc., Technical Report to the Office of Naval Research, August 1967.
- Kelley, C. R. What adaptive training? Human Factors, 1969, 11(6), 547-556.
- Kelley, C. R., & Kelley, E. S. A manual for adaptive techniques. Technical Report to the Office of Naval Research, Santa Monica, California: Dunlap & Associates, Inc., August 1970.
- Kelley, C. R., & Wargo, M. J. Adaptive techniques for synthetic flight training systems. Technical Report, Naval Training Device Center 68-C-0136-1. Santa Monica, California: Dunlap & Associates, Inc., October 1968.
- Kientzle, M. J. Properties of learning curves under varied distributions of practice. Journal of Experimental Psychology, 1946, 36, 187-211.

- Kientzle, M. J. Ability patterns under distributed practice. Journal of Experimental Psychology, 1949, 39, 532-537.
- Kimble, G. A. An experimental test of a two-factor theory of inhibition. Journal of Experimental Psychology, 1949, 39, 15-23.
- Lowes, A. L., Ellis, N. C., Norman, D. A., & Matheny, W. G. Improving piloting skills in turbulent air using a self-adaptive technique for a digital operational flight trainer. Fort Worth, Texas: Life Sciences, Inc., Technical Report, Naval Training Device Center 67-C-0032-2, August 1968.
- Matheny, W. G. The effective time constant--a new technique for adaptive training. Human Factors, 1969, 11(6), 557-560.
- McGraw, L. W. Comparative analysis of methods of scoring tests of motor learning. The Research Quarterly, 1955, 26, 440-453.
- von Bekesey, G. A new audiometer. Actaolaryng (Stockholm), 1947, 35, 411-422.
- Wood, M. E. Continuously adaptive versus discrete changes of task difficulty in the training of a complex perceptual-motor skill. Procedures of American Psychological Association 77th Annual Convention, 1969.

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